

**Research Related to Transportation of Juvenile Salmonids on the Snake River, 2005:  
Final report for the 2002 Spring/Summer  
Chinook Salmon Juvenile Migration**

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## EXECUTIVE SUMMARY

The National Marine Fisheries Service began annual studies in 1995 to evaluate the efficacy of transporting Snake River spring/summer Chinook salmon smolts. From March to August 2005, we recovered 52 age-3-ocean spring/summer Chinook salmon adults, completing adult returns from smolts tagged during the 2002 study year.

In 2002, we tagged only wild fish and released them either into the Lower Granite Dam tailrace or onto a barge at Lower Granite Dam. For analysis, the inriver migrant group was compared with two transport groups: one transported directly from Lower Granite Dam (LGR) and a second collected and transported from Little Goose Dam (LGS). The inriver migrant group excluded any fish detected at a Snake River dam after collection and tagging at LGR.

Based on all 2002 returns combined (age-1-ocean through age-3-ocean fish), the smolt-to-adult return rates (SARs) of fish transported from Lower Granite Dam, transported from Little Goose Dam, and released to migrate in the river were 1.25, 1.02 and 0.76, respectively. These results produced transport-to-inriver migrant ratios (T/Is) of 1.64 (95% CI, 1.36-1.97) for fish transported from Lower Granite Dam and 1.34 (95% CI, 1.07-1.60) for fish transported from Little Goose. We also observed a ratio of 1.22 for Lower Granite-to-Little Goose transport groups. As in previous years, SARs were variable over the course of the juvenile migration. The estimate of annual post hydropower-system differential delayed mortality, “D,” was 0.84.

Nearly 86% of adults from both transported and migrant groups that were detected at Bonneville Dam migrated successfully to Lower Granite Dam (not adjusted for any take in the Zone 6 fishery). Travel time from Bonneville Dam to Lower Granite Dam was approximately 12 d for both transported and migrant age-2-ocean fish, while age-3-ocean fish were a little slower, averaging approximately 13 d for both the inriver-migrant and LGR transport groups and 16 d for the LGS transport group.



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## INTRODUCTION

In 2005, we continued studies to evaluate transportation of juvenile fish as a means to mitigate for downstream losses that result from the lower Snake and Columbia River federal hydropower system. The primary objective of our studies is to compare adult returns of wild yearling Chinook salmon PIT-tagged as smolts and transported to a release site below Bonneville Dam to those of their cohorts allowed to migrate under optimal conditions for inriver survival. Detections from PIT-tagged smolts released to migrate also provide data for short-term survival estimates between the point of release and Bonneville Dam tailrace (Muir et al. 2001).

Here we report final results from the 2002 spring/summer Chinook salmon tagging year at Lower Granite Dam, which was completed with the recovery of age-3-ocean adults in 2005. Information is also provided on tagging effort for the juvenile transportation study during 2005 (Appendix B) and on complete returns from the 1995-2001 tagging years and incomplete adult returns from the 2003-2004 tagging years (Appendix C).

During transportation study years 1995-1996 and 1998-1999, we PIT-tagged wild yearling Chinook salmon smolts at Lower Granite Dam to compare adult returns of smolts transported to below Bonneville Dam with those of smolts released to the tailrace of Lower Granite Dam to migrate in the river. Migrating smolts collected at downstream dams were returned to the river to continue their migration.

However, in evaluating adult returns from those years (and from fish PIT-tagged in the same years upstream of Lower Granite Dam), we found that smolts bypassed and returned to the river at downstream dams survived to adulthood at lower rates than those bypassed only at Lower Granite Dam. Furthermore, fish not detected at dams (fish that passed via spillways, passed through turbines, or were not detected at juvenile fish facilities) returned at higher rates than fish bypassed at downstream collector dams (Williams et al. 2005).

Thus, in hindsight, the study designs from 1995 through 1999 did not provide sufficient information to compare the returns of non-detected/non-transported fish to those of fish that were transported. We therefore revised the study design in 2000 to compare SARs of transported fish only to those of inriver migrants with no detection history on the Snake River other than initial collection and tagging. In addition, the study was modified to use only wild fish, since these are the populations of concern.



## METHODS

### Sampling and Tagging of Juveniles

Since the inception of annual transport studies in 1995, we have collected and PIT-tagged wild Snake River spring/summer Chinook salmon at Lower Granite Dam and released transported and inriver-migrant groups from this dam. However, in 2000 this protocol was changed. Instead of transporting fish from Lower Granite Dam, all tagged fish were released into the Lower Granite Dam tailrace and allowed to migrate down river. To create the transport study group, we set the separation-by-code PIT-tag diversion system at Little Goose Dam to divert 80% of the fish collected at the juvenile fish facility to transportation. The remaining 20% of bypassed fish were used to help develop survival estimates necessary to estimate differential delayed mortality ('D') of transported fish.

In 2002, we reintroduced a transport group from Lower Granite Dam, creating three groups for analysis. Instead of releasing all PIT-tagged fish into the Lower Granite Dam tailrace as in 2000, we tagged additional fish for this group and loaded them into a barge at Lower Granite Dam. The migrant group was composed of fish not detected at either Little Goose or Lower Monumental Dam, consistent with the protocol in 2000. These non-detected fish better represented the general population of wild, unmarked fish that migrated through the Snake River under optimal conditions for survival (i.e., without detection at a Snake River collector dam).

To determine release-group sizes, we calculated the number of fish required to test a null hypothesis, that there is no difference between the SARs of transported and migrant fish, vs. the alternative hypothesis, that the T/I ratio was 1.4 or greater. For a given type I error rate ( $t_{\alpha/2}$ , rejection of a true null hypothesis) and type II error rate ( $t_{\beta}$ , acceptance of a false null hypothesis), the number of fish needed for tagging was determined as

$$\ln\left(\frac{T}{I}\right) - \left(t_{\frac{\alpha}{2}} + t_{\beta}\right) \times SE\left(\ln\left(\frac{T}{I}\right)\right) \approx 0 \quad (1)$$

and

$$SE\left(\ln\frac{T}{I}\right) = \sqrt{\left(\frac{1}{n_T} + \frac{1}{n_I}\right)} = \sqrt{\frac{2}{n}} \quad (2)$$

where  $n$  is the number of adult returns per treatment (for either  $n_T$  transport or  $n_I$  migrant groups). The previous two statements imply that the sample of adults needed is:

$$n = \frac{2\left(t_{\frac{\alpha}{2}} + t_{\beta}\right)^2}{\left(\ln\left(\frac{T}{I}\right)\right)^2} \quad (3)$$





Therefore, if  $\alpha = 0.05$  and  $\beta = 0.20$ , and if we wish to discern a difference of 40% ( $T/I = 1.4$ ), and we expect a transport SAR of at least 2.1% for each species, the sample sizes needed at Lower Granite Dam are:

$$\begin{aligned}n &= 142 \\N_T &= 6,800 \\N_I &= 9,520 \\ \text{Total juveniles} &= 16,320\end{aligned}$$

Where  $N_T$  is the number of juveniles needed for the transport cohort and  $N_I$  is the number of fish needed for the migrating cohort ( $6,800 \times 1.4$ ).

In 1995, 29.7% of the yearling Chinook salmon smolts that we released into the Lower Granite Dam tailrace were never again detected. In 2000, we conservatively estimated that at least 20% of the wild yearling Chinook salmon smolts released into the Lower Granite Dam tailrace would not be detected thereafter. Therefore, to provide the 9,520 fish for the non-detected group would require a release of approximately 47,600 fish ( $9,520/0.2$ ) into the Lower Granite Dam tailrace.

This number also provided sufficient smolts for collection at Little Goose Dam to form a transport test group. For example, assuming an approximate 40% collection efficiency at Little Goose Dam, 19,400 ( $47,600 \times 0.4$ ) wild yearling Chinook salmon smolts would be collected for transport at that dam. The Lower Granite Dam transport group required an additional 6,800 fish.

Marked fish were held an average of 24 h before transport or release into the Lower Granite Dam tailrace with tailrace releases made in the early morning. Basic collection and handling followed the methodology described by Marsh et al. (1996, 2001). We continued using the re-circulating anesthetic water system described in Marsh et al. (2001).

In 2002, we began tagging larger blocks of fish at the beginning and end of the migration season. This design was used to avoid the loss of statistical power from low numbers early and late in the season, which we had encountered in previous study years. When we tagged in proportion to the general population arriving at Lower Granite Dam, results using the lower numbers at the early and late ends of the juvenile migration period had little or no statistical power.

## **Inriver Migration**

Marsh et al. (1996) provided details on how migrating PIT-tagged fish were tracked as they passed through the collection systems at dams downstream from Lower Granite Dam during this study. Prior to 11 July 2002, the McNary Dam juvenile collection facility was in "bypass mode," meaning all tagged and untagged fish collected (except tagged fish from our Columbia River hatchery study) were bypassed to the river after passing through PIT-tag detectors.

Thus, fish from our releases that passed McNary Dam prior to 11 July were included in the study (as inriver migrants). After 11 July 2002, all non-tagged fish collected at this dam were transported, so we excluded any fish bypassed after this date. At Little Goose and Lower Monumental Dams, fish detected on coils leading to the raceways were assumed to have been transported, while fish detected on diversion system coils were assumed to have been returned to the river.

## **Adult Recoveries and Data Analysis**

In 2005, we completed the recovery of adults tagged as juveniles in 2002. To determine the number of juvenile fish in the Little Goose Dam (LGS) transport group and in the inriver migrant groups, we used the methods of Marsh et al. (1996) as modified by Sandford and Smith (2002). A brief explanation of these procedures can be found in Appendix D.

To calculate 95% CIs for various T/Is, release days were pooled until a minimum of two adults returned in both transport and inriver categories. Empirical variance estimates were calculated using these temporal replicates. Daily (or multiple-day pooled) facility collection numbers were used to weight the replicates to provide weighted seasonal T/Is applicable to the untagged population. The weighted mean T/Is and CIs were then constructed on the natural logarithm scale (i.e., such ratio data were assumed to be log-normally distributed) and back-transformed.



## RESULTS

### Sampling and Tagging of Juveniles

We PIT-tagged 39,561 wild yearling spring/summer Chinook salmon from 10 April through 11 June 2002 (Table 1 and Appendix Table A1). The number of fish tagged daily ranged from 35 to 1,762. Of the 39,561 fish tagged, 34,059 were released into the tailrace, and 4,963 were transported in barges from Lower Granite Dam. Of the 34,059 wild yearling Chinook salmon released into the tailrace, 9,827 and 5,399 tagged fish (first detection below Lower Granite Dam) were collected and transported from Little Goose and Lower Monumental Dams, respectively.

Based on mortality counts from the holding tanks at Lower Granite Dam, post-marking delayed mortality (24-hour) averaged 0.7% for yearling Chinook salmon over the entire tagging season. This value is exceptionally low, considering that we tagged virtually every fish sampled. Only a few fish that were either severely injured or exhibited gross symptoms of bacterial kidney disease were rejected for tagging.

By tracking the unique PIT-tag code of each mortality, we determined the body condition recorded when each fish was tagged. As in past years (Marsh et al. 1996, 1997, 2000), descaling affected post-marking delayed mortality for yearling Chinook salmon. When tagged, 0.7% of all fish were recorded as descaled; however, of the delayed mortalities, 4.3% were fish that had been recorded as descaled during tagging.

We recorded fork lengths of all fish during tagging. To avoid tagging spring/summer Chinook salmon of hatchery origin that had partial or no fin clips (identifying them as hatchery fish), we set the maximum fork length for a fish to be considered wild at 124 mm. Based on previous analyses of known wild fish collected and measured during their juvenile migration (Marsh et al. 2001), this limited the number of hatchery fish marked while keeping to a minimum the number of wild fish inadvertently excluded.

Table 1. Numbers and mean fork length of wild juvenile spring/summer Chinook salmon smolts PIT-tagged and released as part of the Lower Granite Dam transportation study, 2002.

Spring/summer Chinook salmon		
	Number	Mean fork length (mm)
Transported from Lower Granite Dam		
Tagged	5,008	107.8
Released*	4,963	107.8
Released into the Lower Granite Dam tailrace		
Tagged	34,553	106.7
Released*	34,059	106.7
Transported from Little Goose Dam		
Released	9,824	106.9

\* Release numbers adjusted for mortality and tag loss.

## Inriver Migration

As inriver study fish continued their seaward migration, some were detected at dams downstream from Lower Granite Dam. Of the 34,059 wild yearling (spring/summer) Chinook salmon tagged and released in the Lower Granite Dam tailrace as inriver migrants, 13,717 (40.3%) were never detected in the Snake River after tagging. Of the 20,342 (59.7%) inriver migrants detected, 9,827 were transported from Little Goose Dam, 6,366 were transported from Lower Monumental Dam (5,399 of the 6,366 were detected for the first time after tagging at Lower Granite Dam), and 4,149 were detected and returned to the river at one or more Snake River dams (Table 2 and Appendix Tables A2-A5). This migration history data was analyzed using the methods of Sandford and Smith (2002), which resulted in estimates of 10,569 and 11,842 juvenile fish in the 2002 Little Goose transport group and inriver migrant group, respectively. All SAR calculations were based on these numbers.

Table 2. Summary of PIT-tagged spring/summer Chinook salmon smolts included in transportation evaluation and final disposition of fish released at Lower Granite Dam and subsequently detected at Little Goose Dam in spring, 2002.

Last coil observation	Final disposition	Number detected at Little Goose Dam
<b>Excluded from transportation study</b>		
Diversion or river return	River	3,087
Raceway	River*	0
Separator	Unknown	49
Total returned to river		3,136
<b>PIT-tagged fish included in study</b>		
Raceway	Loaded to barge/truck and transported	9,652
SMP sample	Smolt Monitoring Program sample	175
Total transported		9,827
<b>Total observed at Little Goose Dam</b>		<b>12,963</b>

\* Because fish cannot be held in transportation loading raceways longer than 48 h, these raceways must be emptied into the river in cases of delayed loading.

At both Little Goose and Lower Monumental Dams, our initial goal was to transport 80% of the yearling Chinook salmon collected. However, the respective proportions of yearling Chinook salmon collected at Little Goose and Lower Monumental Dams and diverted for transportation were only 75.7 and 73.9%.

Based upon PIT-tag detections at John Day and Bonneville Dams and on estuary detections in the pair-trawl system (Ledgerwood et al. 2004) we made preliminary estimates of survival from Lower Granite Dam tailrace to McNary and Bonneville Dam tailraces. For wild spring/summer Chinook salmon smolts, we estimated survivals of 70.7 and 39.2% over the two respective reaches.

### Adult Recoveries and Data Analysis

We began recovering jacks from the 2002 releases at Lower Granite Dam in 2003, and in August 2005, we completed recoveries from this release year with the collection of age-3-ocean adults. Returns by study group and age-class are shown in Table 3, with juvenile numbers adjusted as described by Sandford and Smith (2002). The percentage of wild age-3-ocean adults in 2005 (from our tagging) was the third lowest we have observed since we started transport studies in 1995 (Table 4).

Table 3. Wild spring/summer Chinook salmon returns by study group and age-class, with juvenile numbers adjusted as described by Sandford and Smith (2002) for fish tagged at Lower Granite Dam in 2002.

Juvenile numbers	Returns by Age-class			SAR	T/I	95%	
	Jack	2-ocean	3-ocean			C.I.	LGR/LGS
Inriver Migrants							
11,842	7	70	13	0.76			
Transported from Lower Granite Dam							
4,963	8	42	12	1.25	1.64	(1.36-1.97)	1.22
Transported from Little Goose Dam							
10,569	10	71	27	1.02	1.34	(1.07-1.60)	



Table 4. Age-class distribution of returning adults by study year for Snake River wild spring/summer Chinook salmon transportation studies.

Study year	Jacks (%)	2-ocean adults (%)	3-ocean adults (%)	Total adults
1995	0.0194	0.6323	0.3484	55
1996	0.0625	0.6250	0.3125	16
1998	0.0690	0.7011	0.2299	87
1999	0.0427	0.8110	0.1463	328
2000	0.0383	0.4037	0.5580	832
2001	0.1321	0.7107	0.1572	159
2002	0.0849	0.7260	0.1890	365

As in previous years, the SARs of both transported and migrant groups differed with timing of juvenile release, although the differences were less than seen previously (Figures 1 and 2). The SARs of fish released prior to 14 April 2002 were calculated using the low numbers of juveniles released. As in previous years, we observed a slight decrease in the transport SAR just before its sharpest rise, which began in fish that migrated around 16 May 2002. The migrant SAR rose slightly at the same time but dropped off more quickly than the transport SAR.

Estimates of differential delayed mortality (D) also varied with the timing of juvenile migration (Figure 3), as would be expected given the temporal changes in both transport (LGR and LGS combined) and migrant SARs. The overall 'D' value for 2002 was 0.84, but varied from 0.16 to 1.77. Unlike past years wherein 'D' generally increased (approached 1.0) as the timing of juvenile migration grew later, results from 2002 were bimodal, but trended slightly upward with later juvenile migration timing.



Figure 1. Smolt-to-adult return rates by release date for subyearling Chinook smolts tagged in 2002 and either transported from Lower Granite Dam or released to migrate in the river. Data are 5-day running averages of daily juvenile releases, and numbers are adjusted proportional to daily collection numbers at LGR in 2002. The overall transport/inriver migrant ratio was 1.64.

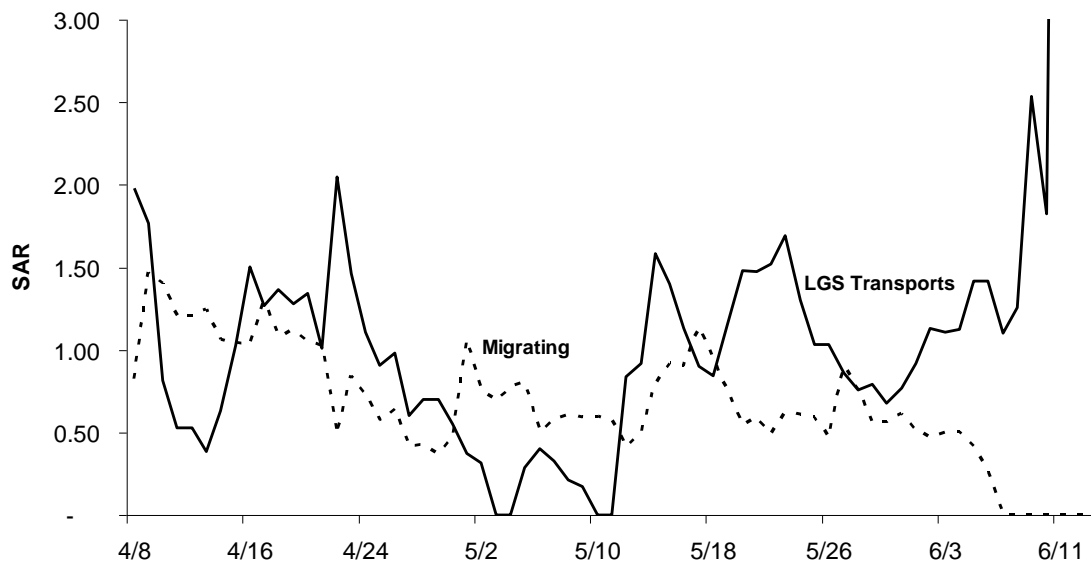


Figure 2. Smolt-to-adult return rates by release date for subyearling Chinook smolts tagged in 2002 and either transported from Little Goose Dam or released to migrate in the river. Data are 5-day running averages of daily juvenile releases, and numbers are adjusted proportional to daily collection numbers at LGS in 2002. The overall transport/inriver migrant ratio was 1.34.

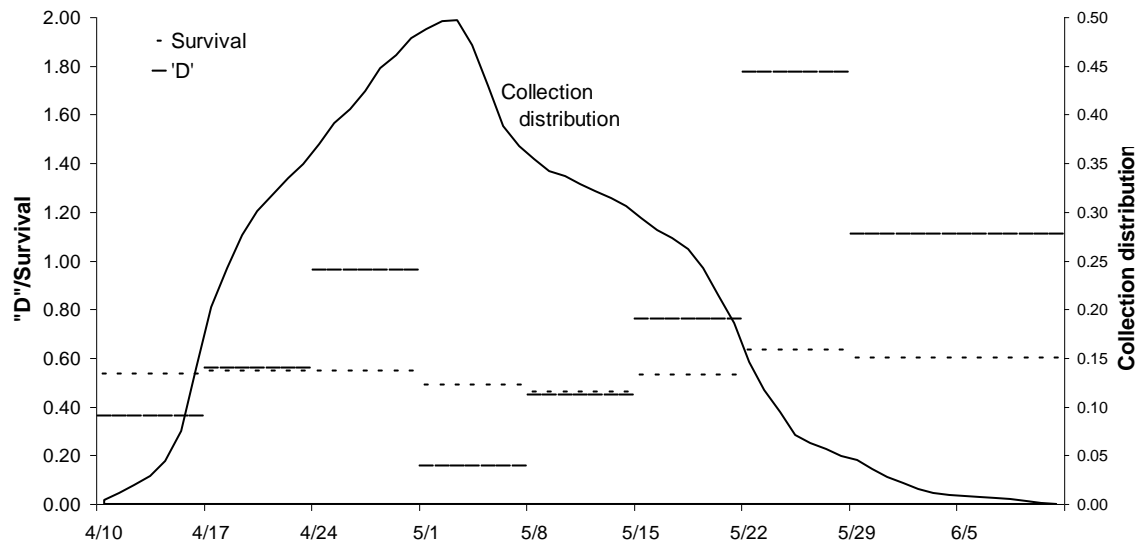


Figure 3. Estimates of differential delayed mortality (D) over time for spring/summer Chinook salmon smolts tagged at Lower Granite Dam in 2002. Grouping is based on having adequate numbers of smolts to estimate inriver survival between Lower Granite and McNary Dams and between McNary and Bonneville Dams. Overall 'D' of the tagged fish for the year was 0.84, while the overall 'D' for the general population was 0.68.

However, because of the blocked tagging design used in 2002, our tagging distribution did not emulate the general population distribution at Lower Granite Dam. By applying the temporal pattern observed for our tagged fish to the general population distribution, we estimated the overall differential delayed mortality (D) for the general population of wild spring/summer Chinook salmon at 0.68.

The number of returning adults observed at Bonneville Dam and subsequently observed at Lower Granite Dam (the conversion rate) was virtually identical for migrant and transport groups (Table 5). Most of the adults that did not successfully migrate from Bonneville Dam to Lower Granite Dam were lost between Bonneville and McNary Dams (Table 6).

In 2003, with the addition of adult detection capabilities at dams on the Columbia River above the confluence with the Snake River, we were able to observe if straying occurred. No adults from the 2002 study strayed above the confluence.

Table 5. Percentage of adult spring/summer Chinook salmon PIT-tagged in 2002 that were observed at Bonneville Dam and subsequently detected at Lower Granite Dam (the conversion rate).

	Number seen at Bonneville Dam	Number seen at Lower Granite Dam	Conversion rate
Jacks			
Migrants	6	6	100.00
LGR Transports	6	6	100.00
LGS Transports	10	9	90.00
Age-2-ocean adults			
Migrants	80	68	85.00
LGR Transports	52	42	80.77
LGS Transports	76	66	86.84
Age-3-ocean adults			
Migrants	16	13	81.25
LGR Transports	15	12	80.00
LGS Transports	28	25	89.29
Totals			
Migrants	102	87	85.29
LGR Transports	73	60	82.19
LGS Transports	114	100	87.72

Table 6. Adult survival (percent) from Bonneville Dam to McNary Dam and from McNary Dam to Lower Granite Dam for wild spring/summer Chinook salmon PIT-tagged and released from Lower Granite Dam in 2002.

Reach	Migration history	Seen at first dam (n)	Subsequently seen at second dam (n)	Survival rate
<b>Jacks</b>				
BON to MCN	Migrant	6	6	100.00
	LGR Transport	6	6	100.00
	LGS Transport	10	9	90.00
MCN to LGR	Migrant	7	7	100.00
	LGR Transport	8	8	100.00
	LGS Transport	9	9	100.00
<b>Age-2-ocean adults</b>				
BON to MCN	Migrant	80	70	87.50
	LGR Transport	52	44	84.62
	LGS Transport	76	68	89.47
MCN to LGR	Migrant	72	70	97.22
	LGR Transport	44	42	95.45
	LGS Transport	71	69	97.18
<b>Age-3-ocean adults</b>				
BON to MCN	Migrant	16	16	100.00
	LGR Transport	15	13	86.67
	LGS Transport	28	26	92.86
MCN to LGR	Migrant	16	13	81.25
	LGR Transport	13	12	92.31
	LGS Transport	28	27	96.43
<b>Totals</b>				
BON to MCN	Migrant	102	92	90.20
	LGR Transport	73	63	86.30
	LGS Transport	114	103	90.35
MCN to LGR	Migrant	95	90	94.74
	LGR Transport	65	62	96.38
	LGS Transport	108	105	97.22

Upstream travel times from Bonneville to Lower Granite Dam ranged from 9.0 to 16.0 d (Table 7). Travel times increased with each age class, but were similar between treatment groups. For both age-2-ocean and age-3-ocean adults, travel time between Bonneville and McNary Dam was roughly the same as between McNary and Lower Granite Dam. For LGR and LGS transported fish, average tagging length decreased slightly as the age of returning adults increased (Table 8).

Table 7. Travel times from Bonneville Dam to Lower Granite Dam for adult spring/summer Chinook salmon PIT-tagged as juveniles in 2002.

Age class	Migration history	Travel time from
		Bonneville Dam to Lower Granite Dam (d)
Jacks	Inriver migrants	9.5
	Transported LGR	9.0
	Transported LGS	9.0
Age-2-ocean	Inriver migrants	11.5
	Transported LGR	12.0
	Transported LGS	11.0
Age-3-ocean	Inriver migrants	13.0
	Transported LGR	13.5
	Transported LGS	16.0

Table 8. Average tagging lengths of adult wild spring/summer Chinook salmon  
PIT-tagged as juveniles at Lower Granite Dam in 2002.

Age class		Number of adults	Average length as juveniles at tagging of returning adults (mm)
Jacks	Migrant	7	110.1
	LGR Transport	8	111.5
	LGS Transport	9	110.4
	Total	24	110.4
Age-2-ocean	Migrant	70	106.7
	LGR Transport	40	111.3
	LGS Transport	71	108.2
	Total	181	108.1
Age-3-ocean	Migrant	13	111.6
	LGR Transport	11	110.5
	LGS Transport	27	107.2
	Total	51	109.0





## DISCUSSION

For most transport studies conducted on spring/summer Chinook salmon smolts since 1995, annual T/Is, while indicating a transport benefit, were lower than expected when compared to concurrent estimates of inriver survival (Marsh et al. 2000, 2001; Muir et al. 2001). In contrast to all previous studies, contemporary study designs and the use of PIT tags allow for a more refined analysis of SARs and T/Is than a simple calculation of an annual average.

Calculating the statistics for groups of fish by the period when they were marked as smolts has revealed an interesting time trend in the data. Recent annual T/Is have been lower than expected, primarily because transport SARs were much lower for fish tagged as smolts earlier than for those tagged later in the migration season. The timing of the rather abrupt increases in transport SARs has been inconsistent among study years. In general, transport benefits are equivocal early in the season and at roughly expected levels later in the season. As a result, when averaged over the entire juvenile migration season, overall T/Is were lower than expected.

As shown in the table below, the transition date from low to high transport SARs has varied during previous study years. Transition dates have ranged from 22 April to 6 May (Marsh et al. 2000, 2003, 2004a, 2004b, 2005). The transition date during the 2002 juvenile migration was 16 May, the latest date observed in the current sequence of studies.

<u>Study year</u>	<u>Transition date of the rise in SARs for transported fish</u>
1995	5 May
1998	25 April
1999	22 April
2000	6 May
2001	26 April
2002	16 May

Originally, the observed within-year changes in SARs were peculiar and unexpected. To the best of our knowledge, the rather abrupt within-year increases in transport SARs were not related to any environmental or biological factor that has been examined during the freshwater phase. A rather significant, post-release phenomenon appears to have affected the survival of transported fish during most of April and then

dissipated quickly. The SARs of migrants PIT-tagged and released in April may not have been similarly affected because the great majority of these fish would have arrived below Bonneville Dam 2-3 weeks later than the transported fish.

We have not observed any temporal differences in migration behavior, physiology, disease, or transport methodologies that might explain the abrupt and sustained seasonal changes in SARs of transported fish. We believe the pattern relates to arrival timing of smolts in the estuary and near-ocean environments. Conditions that might vary annually in these areas include predator abundance and dynamics (birds, fish, and marine mammals), alternative prey availability for those predators (anchovies, herring, and sand lance), and abundance of prey for juvenile salmon (enhanced survival of fast-growing, robust smolts) (Emmett and Brodeur 2000; Emmett et al. 2006). Changes in predator/prey dynamics coincidental with the 1976/1977 oceanic regime shift (Hare et al. 1999), particularly during early ocean residence (Hargreaves 1997), likely play a major role in determining annual SARs and high within- and between-year variation in SARs.

Muir et al. (in prep.) theorize that size-related predation is a cause of post-hydropower system delayed mortality, particularly for wild spring/summer Chinook salmon. The growth that migrant fish experience during their 2-3 week journey to the estuary allows them to reach a large enough size that fewer piscivorous predators can consume them. Early season transported fish lack the opportunity for growth, thereby, reaching the estuary at a size that makes them more vulnerable to predation.

For example, in 2002, nearly 70% of early transported wild yearling Chinook salmon were susceptible to northern pikeminnow predation based on size, while less than 60% of inriver migrants marked at the same time were susceptible. In the same year, over 80% of early transported fish were susceptible to Pacific hake predation compared to only 50% of their inriver migrant cohorts.

Conversion rates of adults from Bonneville Dam to Lower Granite Dam were similar for the two transport groups and the inriver migrants. As we have seen in the past, more fish were lost between Bonneville and McNary Dams than between McNary and Lower Granite Dams. However, when the Zone 6 fishery is factored in, the conversion rates are virtually the same. For example, the average conversion rate for age-2-ocean adults (in 2004) between Bonneville and McNary Dams was 87.5%, without accounting for the Zone 6 fishery. The Zone 6 fishery's estimated take in 2004 was 8.5%. Adjusting the Bonneville Dam to McNary Dam conversion rate for the fishery yields a conversion rate of 96.0%, virtually matching the McNary Dam to Lower Granite Dam conversion rate of 96.8%.

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## **APPENDIX A**

### **Juvenile Data from the 2002 Spring/Summer Chinook Salmon Tagging Year**

Appendix Table A1. Total wild spring/summer Chinook salmon tagged at Lower Granite Dam in spring 2002.

Tag date	Transported from Lower Granite Dam		Released into Lower Granite Dam tailrace			
	Tagged	Released	Tagged	Post-tagging		
				mortality	Lost tags	Released
09-Apr	35	35	222	1	1	220
10-Apr	-	-	421	1	-	420
11-Apr	192	192	835	1	-	834
12-Apr	-	-	887	5	-	882
13-Apr	122	122	-	-	-	-
14-Apr	-	-	-	-	-	-
15-Apr	149	149	1,009	2	-	1,007
16-Apr	-	-	1,347	22	5	1,320
17-Apr	261	261	387	3	-	384
18-Apr	-	-	1,193	4	-	1,189
19-Apr	346	346	951	5	-	946
20-Apr	-	-	-	-	-	-
21-Apr	-	-	-	-	-	-
22-Apr	60	60	382	3	-	379
23-Apr	71	71	453	1	-	452
24-Apr	156	156	981	6	1	974
25-Apr	129	129	755	-	-	755
26-Apr	252	252	1,510	3	-	1,507
27-Apr	-	-	-	-	-	-
28-Apr	-	-	-	-	-	-
29-Apr	66	66	382	1	-	381
30-Apr	38	38	255	3	-	252
01-May	60	60	380	12	-	368
02-May	77	77	552	3	-	549
03-May	99	99	573	-	-	573
04-May	-	-	-	-	-	-
05-May	-	-	-	-	-	-
06-May	73	73	433	2	-	431
07-May	32	32	337	25	-	312
08-May	92	92	943	18	-	925
09-May	55	55	745	4	-	741



Appendix Table A1. Continued.

Tag date	Transported from Lower		Released into Lower Granite Dam tailrace			
	Granite Dam		Released into Lower Granite Dam tailrace			
	Tagged	Released	Tagged	Post-tagging mortality	Lost tags	Released
10-May	42	42	499	6	-	493
11-May	-	-	-	-	-	-
12-May	-	-	-	-	-	-
13-May	54	54	611	1	-	610
14-May	46	46	499	1	-	498
15-May	44	44	562	1	-	561
16-May	28	28	397	6	-	391
17-May	42	42	622	24	-	598
18-May	27	27	778	2	-	776
19-May	44	44	1,063	12	-	1,051
20-May	129	129	802	2	1	799
21-May	221	221	1,308	5	-	1,303
22-May	192	192	1,069	7	-	1,062
23-May	138	138	809	3	-	806
24-May	335	335	926	3	-	923
25-May	-	-	1,070	3	-	1,067
26-May	125	125	724	3	-	721
27-May	-	-	-	-	-	-
28-May	124	124	708	7	-	701
29-May	-	-	621	2	-	619
30-May	259	259	909	8	-	901
31-May	124	124	676	4	-	672
01-Jun	139	139	905	4	-	901
02-Jun	159	159	902	3	-	899
03-Jun	-	-	886	3	-	883
04-Jun	220	220	410	-	-	410
05-Jun	-	-	378	-	-	378
06-Jun	115	115	275	-	-	275
07-Jun	-	-	180	-	-	180
08-Jun	32	32	-	-	-	-
09-Jun	-	-	-	-	-	-
10-Jun	4	4	31	-	-	31

Appendix Table A2. Observations (detections) and transportation numbers at Little Goose Dam of spring/summer Chinook salmon released into the Lower Granite Dam tailrace, 2002.

Tag group	Total observed	Number transported	Percent transported
DMM02099.IR1	191	146	76.4
DMM02100.IR1	224	175	78.1
DMM02101.IR1	316	241	76.3
DMM02101.IR2	208	155	74.5
DMM02102.IR1	254	193	76.0
DMM02102.IR3	263	205	77.9
DMM02105.IR1	269	207	77.0
DMM02105.IR3	278	213	76.6
DMM02106.IR1	362	282	77.9
DMM02106.IR3	287	214	74.6
DMM02107.IR1	118	92	78.0
DMM02107.IR2	276	197	71.4
DMM02108.IR1	337	256	76.0
DMM02108.IR2	582	436	74.9
DMM02109.IR1	296	228	77.0
DMM02109.IR2	417	320	76.7
DMM02112.IR1	167	124	74.3
DMM02112.IR2	74	56	75.7
DMM02113.IR1	138	111	80.4
DMM02113.IR2	175	140	80.0
DMM02114.IR1	340	268	78.8
DMM02114.IR2	158	123	77.8
DMM02115.IR1	328	254	77.4
DMM02115.IR2	64	51	79.7
DMM02116.IR1	614	452	73.6
DMM02116.IR2	68	56	82.4
DMM02119.IR1	185	130	70.3
DMM02119.IR2	140	106	75.7
DMM02120.IR1	129	93	72.1
DMM02120.IR2	157	113	72.0
DMM02121.IR1	161	114	70.8
DMM02121.IR2	79	56	70.9
DMM02122.IR1	225	157	69.8
DMM02122.IR2	115	86	74.8
DMM02123.IR1	135	100	74.1
DMM02123.IR2	77	58	75.3
DMM02126.IR1	104	70	67.3
DMM02126.IR2	30	25	83.3
DMM02127.IR1	161	114	70.8
DMM02128.IR1	392	272	69.4
DMM02129.IR1	208	139	66.8
DMM02129.IR2	133	98	73.7

Appendix Table A2. Continued.

Tag group	Total observed	Number transported	Percent transported
DMM02130.IR1	270	201	74.4
DMM02133.IR1	133	93	69.9
DMM02133.IR2	159	109	68.6
DMM02134.IR1	180	132	73.3
DMM02134.IR2	94	69	73.4
DMM02135.IR1	190	147	77.4
DMM02135.IR2	145	110	75.9
DMM02136.IR1	128	99	77.3
DMM02136.IR2	218	155	71.1
DMM02137.IR1	275	203	73.8
DMM02137.IR2	346	265	76.6
DMM02138.IR1	865	640	74.0
DMM02139.IR1	1,290	960	74.4
DMM02139.IR2	78	61	78.2
DMM02140.IR1	515	386	75.0
DMM02140.IR2	710	562	79.2
DMM02141.IR1	466	353	75.8
DMM02141.IR2	209	163	78.0
DMM02142.IR1	1,220	974	79.8
DMM02142.IR2	35	28	80.0
DMM02143.IR1	931	735	78.9
DMM02143.IR2	55	45	81.8
DMM02144.IR1	1,232	961	78.0
DMM02144.IR2	446	349	78.3
DMM02145.IR1	1,026	795	77.5
DMM02145.IR2	495	394	79.6
DMM02146.IR1	664	526	79.2
DMM02146.IR2	883	655	74.2
DMM02148.IR1	927	730	78.7
DMM02148.IR2	11	10	90.9
DMM02149.IR1	1,010	777	76.9
DMM02149.IR2	10	6	60.0
DMM02150.IR1	971	764	78.7
DMM02150.IR2	55	39	70.9
DMM02151.IR1	867	664	76.6
DMM02151.IR2	32	24	75.0
DMM02152.IR1	851	664	78.0
DMM02152.IR2	132	99	75.0
DMM02153.IR1	586	469	80.0
DMM02154.IR1	252	208	82.5
DMM02154.IR2	6	6	100.0
DMM02155.IR1	215	173	80.5
DMM02156.IR1	410	317	77.3
DMM02157.IR1	251	204	81.3
DMM02158.IR1	156	128	82.1
DMM02161.IR1	89	78	87.6
DMM02162.IR1	48	35	72.9
DMM02163.IR1	78	63	80.8

Appendix Table A3. Locations of observations (detections) of PIT-tagged juvenile spring/summer Chinook salmon within the Little Goose Dam juvenile fish facility, 2002.

Detection date	Detected once at Little Goose Dam (coil location)				Detected on separator and one additional coil (coil location)		
	Diversion	Raceway	Sample	Separator	Diversion	Raceway	Sample
12-Apr	-	-	-	-	2	4	1
13-Apr	-	-	-	-	9	27	2
14-Apr	-	-	-	2	32	125	7
15-Apr	-	1	-	-	54	203	10
16-Apr	-	-	-	1	41	146	1
17-Apr	-	-	-	-	32	111	5
18-Apr	-	-	-	-	51	187	3
19-Apr	-	-	-	1	79	215	8
20-Apr	-	-	-	1	65	210	9
21-Apr	-	-	-	-	101	276	12
22-Apr	-	-	-	2	66	246	4
23-Apr	1	2	-	4	132	315	10
24-Apr	-	-	-	2	59	190	4
25-Apr	-	-	-	1	39	159	3
26-Apr	-	-	-	-	56	200	8
27-Apr	1	-	-	-	61	254	6
28-Apr	-	1	-	1	40	152	3
29-Apr	1	-	-	2	59	205	5
30-Apr	-	-	-	1	72	250	3
1-May	-	-	-	4	112	381	5
2-May	1	-	-	3	146	450	6
3-May	-	-	-	3	158	460	2
4-May	-	-	-	3	167	434	2
5-May	-	-	-	-	125	267	-
6-May	-	1	-	3	78	230	1
7-May	-	-	-	1	45	148	-
8-May	-	-	-	-	21	61	-
9-May	-	-	-	-	5	16	-
10-May	-	1	-	1	12	38	-
11-May	-	-	-	2	23	60	1
12-May	-	-	-	-	36	120	3
13-May	2	-	-	-	89	158	4
14-May	2	-	-	-	84	218	2
15-May	-	1	-	1	77	195	1
16-May	-	1	-	1	36	109	1
17-May	-	-	-	-	112	243	3
18-May	-	1	-	-	73	228	-
19-May	-	1	-	1	74	238	3

Appendix Table A3. Continued.

Detection date	Detected once at Little Goose Dam (coil location)				Detected on separator and one additional coil (coil location)		
	Diversion	Raceway	Sample	Separator	Diversion	Raceway	Sample
20-May	-	1	-	2	162	469	2
21-May	-	-	-	3	291	800	3
22-May	1	3	-	4	339	1,060	6
23-May	-	2	-	2	292	993	3
24-May	-	-	-	6	136	422	6
25-May	-	1	-	3	124	453	3
26-May	-	-	-	2	146	558	8
27-May	-	-	-	5	199	722	9
28-May	1	1	-	2	204	778	14
29-May	-	2	-	9	375	1,265	17
30-May	-	2	-	6	314	1,085	20
31-May	-	-	1	6	302	1,042	14
1-Jun	-	2	-	8	319	1,100	12
2-Jun	-	1	-	5	201	755	14
3-Jun	-	2	1	3	196	746	19
4-Jun	-	1	-	-	175	586	11
5-Jun	-	-	-	7	119	461	6
6-Jun	-	1	-	1	50	194	7
7-Jun	-	-	-	2	46	178	7
8-Jun	-	-	-	1	76	276	22
9-Jun	-	-	-	-	59	230	17
10-Jun	-	-	-	-	47	186	10
11-Jun	-	-	-	-	13	53	5
12-Jun	-	-	-	-	5	15	-
13-Jun	-	-	-	-	2	11	2
14-Jun	-	-	-	-	9	25	9
15-Jun	-	-	-	1	10	38	6
16-Jun	-	-	-	-	7	29	4
17-Jun	-	-	-	-	5	13	6
18-Jun	-	-	-	-	5	14	2
19-Jun	-	-	-	-	3	12	-
20-Jun	-	-	-	-	1	8	1
21-Jun	-	-	-	-	2	2	-
22-Jun	-	-	-	-	1	6	-
23-Jun	-	-	-	-	1	2	-
24-Jun	-	-	-	-	-	1	1
25-Jun	-	-	-	-	1	3	-
26-Jun	-	-	-	-	-	1	-
29-Jun	-	-	-	-	1	1	-
30-Jun	-	-	-	-	-	1	-
3-Jul	-	-	-	-	-	1	-
11-Jul	-	-	-	-	-	1	-
15-Jul	-	-	-	-	1	-	-

Appendix Table A4. Locations of observations (detections) of PIT-tagged spring/summer Chinook salmon within the Lower Monumental Dam juvenile fish facility, 2002.

Detection date	Detected once at Lower Monumental Dam (coil location)				Detected on separator and one additional coil (coil location)		
	Diversion	Raceway	Sample	Separator	Diversion	Raceway	Sample
15-Apr	-	-	-	-	-	-	1
18-Apr	-	-	-	-	-	-	4
22-Apr	-	-	-	-	-	-	12
25-Apr	-	-	-	1	-	-	8
29-Apr	-	-	-	-	-	-	7
30-Apr	-	-	-	1	61	193	20
1-May	-	-	-	6	114	386	53
2-May	-	-	-	-	79	258	3
3-May	-	-	-	-	79	182	45
4-May	3	1	-	1	287	622	72
5-May	-	-	-	-	81	240	4
6-May	-	1	-	1	34	91	7
7-May	-	-	-	-	189	353	6
8-May	-	-	-	-	60	168	2
9-May	-	-	-	-	45	96	9
10-May	-	-	-	-	97	136	4
11-May	-	1	-	1	59	79	1
12-May	-	-	-	-	21	43	2
13-May	-	-	-	-	49	128	3
14-May	-	-	-	-	38	90	3
15-May	1	-	-	-	32	108	7
16-May	-	-	-	-	81	227	13
17-May	-	-	-	1	90	218	2
18-May	-	-	-	-	59	143	7
19-May	-	-	-	1	181	473	6
20-May	1	1	1	-	118	287	5
21-May	1	1	-	-	120	270	12
22-May	-	-	-	-	253	614	6
23-May	1	-	-	-	150	442	3
24-May	-	-	-	-	151	439	3
25-May	-	-	-	-	123	423	3
26-May	-	-	-	-	57	234	1
27-May	-	-	-	-	35	123	23
28-May	1	1	-	1	183	613	54
29-May	-	-	-	-	139	458	2

Appendix Table A4. Continued.

Detection date	Detected once at Lower Monumental Dam (coil location)				Detected on separator and one additional coil (coil location)		
	Diversion	Raceway	Sample	Separator	Diversion	Raceway	Sample
30-May	-	-	-	3	293	782	65
31-May	-	1	1	1	328	723	64
1-Jun	-	-	1	2	99	304	42
2-Jun	-	4	-	2	73	205	38
3-Jun	1	-	1	3	310	925	126
4-Jun	-	-	-	1	162	548	7
6-Jun	-	-	-	-	112	379	2
7-Jun	-	-	-	-	106	376	13
8-Jun	-	-	-	-	99	315	7
9-Jun	1	-	-	-	67	247	10
10-Jun	-	-	-	-	31	117	3
11-Jun	-	-	-	-	37	146	-
12-Jun	-	-	-	-	37	137	4
13-Jun	-	-	-	-	27	108	1
14-Jun	-	-	-	-	13	46	-
15-Jun	-	-	-	-	8	26	1
16-Jun	-	-	-	-	3	14	1
17-Jun	-	-	-	-	5	21	-
18-Jun	-	-	-	-	12	42	-
19-Jun	-	-	-	-	9	31	-
20-Jun	-	-	-	-	6	27	-
21-Jun	-	-	-	-	4	14	-
22-Jun	-	-	-	-	1	8	-
23-Jun	-	-	-	-	2	4	-
24-Jun	-	-	-	-	1	4	-
25-Jun	-	-	-	-	1	2	-
26-Jun	-	-	-	-	1	2	2
28-Jun	-	-	-	-	-	-	3
29-Jun	-	-	-	-	3	1	9
30-Jun	-	-	-	-	1	2	3
1-Jul	-	-	-	-	-	2	1
2-Jul	-	-	-	-	2	-	1
3-Jul	-	-	-	-	-	-	4
4-Jul	-	-	-	-	1	-	-
5-Jul	-	-	-	-	-	-	1
7-Jul	-	-	-	1	-	-	-

Appendix Table A4. Continued.

Detection date	Detected once at Lower Monumental Dam (coil location)				Detected on separator and one additional coil (coil location)		
	Diversion	Raceway	Sample	Separator	Diversion	Raceway	Sample
8-Jul	-	-	-	-	-	-	1
10-Jul	-	-	-	-	-	2	-
11-Jul	-	-	-	-	1	-	-
14-Jul	-	-	-	-	-	1	-
23-Jul	-	-	-	-	-	2	-
24-Jul	-	-	-	-	-	1	-
25-Jul	-	-	-	-	-	-	-
26-Jul	-	-	-	-	-	1	-
28-Jul	-	-	-	-	-	1	-
30-Jul	-	-	-	-	-	1	-
31-Jul	-	-	-	-	1	-	-
2-Aug	-	-	-	-	-	1	-
4-Aug	-	-	-	-	-	1	-
11-Aug	-	-	-	-	-	2	-
12-Aug	-	-	-	-	1	-	-
14-Aug	-	-	-	-	-	2	-
17-Aug	-	-	-	-	-	-	2
20-Aug	-	-	-	-	1	-	-
21-Aug	-	-	-	-	-	-	1
22-Aug	-	-	-	-	-	-	2
25-Aug	-	-	-	-	1	-	-
28-Aug	-	-	-	-	1	-	1
29-Aug	-	-	-	-	-	-	1
31-Aug	-	-	-	-	-	-	3
5-Sep	-	-	-	-	2	-	-
25-Sep	-	-	-	-	-	-	1
12-Oct	-	-	-	-	1	-	-



Appendix Table A5. Locations of observations (detections) of PIT-tagged spring/summer Chinook salmon within the McNary Dam juvenile fish facility, 2002.

Detection date	Detected once at McNary Dam (coil location)				Detected on separator and one additional coil (coil location)		
	Diversion	Raceway	Sample	Separator	Diversion	Raceway	Sample
17-Apr	-	-	-	-	9	-	1
18-Apr	-	-	-	-	12	-	1
19-Apr	-	-	-	-	25	-	-
20-Apr	-	-	-	-	26	-	-
21-Apr	-	-	-	-	13	-	1
22-Apr	-	-	-	-	18	1	-
23-Apr	-	-	-	-	62	1	2
24-Apr	-	-	-	-	66	2	1
25-Apr	-	-	-	1	93	2	3
26-Apr	-	-	-	-	97	2	-
27-Apr	-	-	-	-	94	-	2
28-Apr	-	-	-	-	117	2	5
29-Apr	-	-	-	-	163	1	2
30-Apr	1	1	-	1	117	2	2
1-May	-	-	-	-	95	-	2
2-May	-	-	-	-	201	-	6
3-May	-	-	-	2	291	4	3
4-May	-	-	-	-	335	11	2
5-May	-	-	-	1	234	3	6
6-May	-	-	-	-	316	3	2
7-May	-	-	-	1	254	8	1
8-May	-	-	-	-	205	7	3
9-May	-	-	-	-	152	4	3
10-May	-	-	-	-	170	5	2
11-May	-	-	-	-	128	6	2
12-May	-	-	-	-	104	2	1
13-May	1	-	-	-	134	9	-
14-May	-	-	-	-	106	6	1
15-May	-	-	-	-	65	5	-
16-May	-	-	-	-	69	2	1
17-May	-	-	-	1	97	6	1
18-May	-	-	-	1	94	2	1
19-May	-	-	-	-	71	3	2
20-May	-	-	-	-	116	6	1
21-May	-	-	-	-	185	6	1
22-May	-	-	-	-	181	7	1

Appendix Table A5. Continued.

Detection date	Detected once at McNary Dam (coil location)				Detected on separator and one additional coil (coil location)		
	Diversion	Raceway	Sample	Separator	Diversion	Raceway	Sample
23-May	1	-	-	-	198	4	4
24-May	-	-	-	-	110	3	1
25-May	-	-	-	2	136	7	2
26-May	-	-	-	1	131	1	2
27-May	-	-	-	-	97	1	1
28-May	-	-	-	-	90	3	1
29-May	-	-	-	-	113	3	2
30-May	-	-	-	-	111	2	2
31-May	-	-	-	1	85	1	2
1-Jun	-	-	1	-	80	-	2
2-Jun	-	-	-	-	92	2	2
3-Jun	-	-	-	-	134	1	8
4-Jun	-	-	-	2	72	-	1
5-Jun	-	-	-	1	49	-	1
6-Jun	1	-	-	-	85	-	2
7-Jun	-	-	-	-	110	-	4
8-Jun	-	-	-	-	80	-	2
9-Jun	1	-	-	1	32	-	1
13-Jun	-	-	-	-	5	-	-
14-Jun	-	-	-	1	19	-	-
15-Jun	-	-	-	-	25	-	-
16-Jun	-	-	-	-	34	-	3
17-Jun	-	-	-	-	10	-	1
18-Jun	-	-	-	-	6	-	-
19-Jun	-	-	-	-	1	-	1
20-Jun	-	-	-	1	3	-	-
21-Jun	-	-	-	-	1	-	-
23-Jun	-	-	-	-	3	-	-
24-Jun	-	-	-	-	3	-	-
25-Jun	-	-	-	-	1	-	-
26-Jun	-	-	-	-	3	-	-
27-Jun	-	-	-	-	2	-	-
28-Jun	-	-	-	-	2	-	-
30-Jun	-	-	-	-	1	-	1
7-Jul	-	-	-	-	1	-	-
10-Jul	-	-	-	-	1	-	-
11-Jul	-	-	-	-	1	-	-
14-Jul	-	-	-	-	1	-	-
19-Jul	-	-	-	-	1	-	-
5-Oct	-	-	-	-	1	-	-

## **APPENDIX B**

### **Tagging Results for 2005 Transportation Studies**

From 12 April through 5 June 2005, we PIT-tagged a total of 12,729 wild yearling smolts, all of which were loaded into barges at Lower Granite Dam. From 12 April through 11 June, we PIT-tagged 10,476 wild steelhead smolts at Lower Granite Dam, all of which were loaded into barges at the dam.



## **APPENDIX C**

### **Adult Returns from Previous and In-progress Studies**

Appendix Table C1. Snake River wild spring/summer Chinook salmon studies.

Tagging year	Juvenile fish numbers			Returns by Age-class			SAR			LGR T/I	LGS T/I	95% C.I. (LGR T/I) (LGS T/I)	Status	Annual report containing final results
	LGR Transport	LGS Transport	Migrant	1-ocean	2-ocean	3-ocean	LGR Transport	LGS Transport	Migrant					
2004	11,208	--	--	2	--	--	--	--	--	--	--	--	In-progress	Fall 2007
2003	7,118	12,843	43,108	2	60	--	--	--	--	--	--	--	In-progress	Fall 2006
												(1.36, 1.97)		
<b>2002 a</b>	<b>4,963</b>	<b>10,569</b>	<b>11,842</b>	<b>25</b>	<b>183</b>	<b>52</b>	<b>1.25</b>	<b>1.02</b>	<b>0.76</b>	<b>1.64</b>	<b>1.34</b>	<b>(1.07, 1.60)</b>	<b>Completed</b>	<b>Current</b>
2001	16,512	--	--	21	113	25	0.95	--	--	--	--	(0.84, 1.11)	Completed	2004
2000 a	17,367	--	26,329	16	263	355	1.47	--	1.44	1.02	--	(0.9, 1.1)	Completed	2003
1999 a	8,384	--	1,920	11	164	27	2.10	--	1.35	1.55	--	(1.0, 2.4)	Completed	2001
1998 a	5,689	--	2,932	6	42	14	0.60	--	0.65	0.63	--	(0.4, 1.0)	Completed	2001
1996 a	7,949	--	3,915	1	8	3	0.11	--	0.08	1.5	--	(0.5, 7.5)	Completed	1999
1995 a	24,066	--	6,794	1	70	36	0.38	--	0.22	1.7	--	(1.1, 2.6)	Completed	1998

a - Juvenile numbers have been modified by Sandford and Smith (2002)

Appendix Table C2. Snake River hatchery spring/summer Chinook salmon studies.

Tagging year	Juvenile fish numbers		Returns by age-class			SAR		T/I	95% C.I.	Status	Annual report containing final results
	Transport	Migrant	Jack	2-ocean	3-ocean	Transport	Migrant				
1999	42,273	16,664	99	935	41	1.97	1.45	1.4	(1.2, 1.6)	Completed	2001
1998	39,596	23,552	48	297	34	0.62	0.57	1.1	(0.9, 1.4)	Completed	2001
1996	35,632	20,186	7	43	22	0.13	0.1	1.2	(0.8, 2.0)	Completed	1999
1995	83,064	25,757	34	444	70	0.54	0.32	1.7	(1.4, 2.1)	Completed	1998





## APPENDIX D

### Overview of Statistical Methodology

For each day of the migration season, we estimated numbers of fish passing each dam, developing a series of daily passage estimates. These daily estimates were used to estimate SARs according to the method of Sandford and Smith (2002). A brief synopsis of this method follows (shown here for Little Goose Dam).

- 1) Fish detected on day  $k$  at Lower Monumental Dam that had previously been detected at Little Goose Dam were grouped according to day of detection (passage) at Little Goose Dam.
- 2) Fish detected on day  $k$  at Lower Monumental Dam that had *not* previously been detected at Little Goose Dam were assigned a day of detection at Little Goose Dam based on the distribution at Little Goose Dam of fish detected at both dams. This step assumed that the passage distribution for non-detected fish at Little Goose Dam was proportionate to that of their cohorts detected at Little Goose Dam.
- 3) This process was repeated for each day of detection at Lower Monumental Dam during the juvenile migration season.
- 4) All fish detected at Lower Monumental Dam were assigned a passage day  $i$  at Little Goose Dam whether or not they had been detected at Little Goose Dam.
- 5) Probability ( $p$ ) of detection at Little Goose Dam on day  $i$  was estimated by comparing the proportion of fish detected on day  $i$  to the total number of fish known to have arrived at the dam on day  $i$ . Numbers were adjusted for fish that had been transported from Little Goose Dam.
- 6) The total number of fish arriving at Little Goose Dam on day  $i$  ( $LGS_i$ ) was estimated by dividing the total number detected at Little Goose Dam on day  $i$  (including bypassed and transported fish) by the estimated probability of detection on day  $i$ .

We then estimated SARs for various detection-history categories, in particular for fish transported from a dam, for fish bypassed back to the river at one or more dams, and for fish never detected at a Snake River dam. To do this, we developed daily passage estimates at Little Goose Dam using the following process:

- 7) For each group that passed Little Goose Dam on day  $i$  ( $LGS_i$ ; see step 5 above), we estimated the probability of detection at Lower Monumental (LMO) and McNary (MCN) Dams using the Cormack-Jolly-Seber single-release model (Cormack 1964; Jolly 1965; Seber 1965).
- 8) We multiplied the group passing Little Goose Dam on day  $i$  by the detection and transport probabilities derived from step 7 to estimate numbers in each detection history category. For example, the detection-history category "not detected at Lower Monumental Dam and then bypassed at McNary Dam" would be expressed as

$$(LGS_i) [1 - p (LMO)] [p (MCN)] [1 - p (transport at MCN)].$$

- 9) We summed the products from step 8 for each day to arrive at the total number of smolts in each detection-history category.

Next we calculated SARs. For a given detection-history category, this was the ratio of the observed number of adults in the category to the estimated number of smolts in that category.

Finally, we estimated the precision of the estimated SARs. This was done using bootstrap methods wherein the individual fish information (i.e., detection history, detection dates, and adult return record) was resampled 1,000 times with replacement (Efron and Tibshirani 1993). Standard errors and confidence limits about the SARs were generated from these bootstrapped estimates.